NEW ELEMENTARY CHEMISTRY

GUIDE

TO

ELEMENTARY CHEMISTRY

FOR BEGINNERS

COOLEY

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PREFACE.

In an Elementary Chemistry, written in 1872, it was my purpose to give a short course, for beginners, in which the experimental evidence, on which the most fundamental parts of the science rested, should take the place of minute details and advanced theoretical discussions, hoping in this way to encourage the study of chemistry by experiment instead of by books alone, as was so much the custom at that day. A *Student's Guide*, printed for the use of my classes in 1878, contained a course introductory to qualitative analysis, giving the student nothing but an outline of experiments. He was expected to make the experiments, to observe and describe his own results, and from these to construct for himself a plan for the detection of the metals. I now combine the leading ideas of those two books, and offer to my fellow-teachers a new volume, in which they are more fully developed in ways suggested by the unbroken experience of the intervening years.

Chemistry as a branch of study in the schools has two great merits happily combined. One is to be found in the kind of knowledge it offers, and the other in the peculiar mental training it affords. Of these the latter is certainly not the least important, because a person is well educated, not so much in proportion to what he knows, as in proportion to what he can do with his knowledge. Hence a chief purpose

of the study of elementary chemistry in schools is to educate the mind by giving it the right kind of exercise in the use of its powers.

I have therefore tried to make a judicious selection of the most fundamental facts and principles of chemistry, and to present these in such a way that the student must constantly use his senses to discover facts, his reason in drawing correct inferences from the data he collects, and good English in expressing accurately what he sees and thinks.

I know of but one way to teach a student how to acquire a real knowledge of nature, and that is, to fix his mind habitually on things and events brought under his own eye, and direct him to the discovery of facts and principles for himself. The use of apparatus is, of course, indispensable if the student is thus to study phenomena instead of descriptions of phenomena, and the use of apparatus, by himself, is without doubt the method which is most certain to stimulate his mind to the greatest activity. Laboratory study for students in high schools is rapidly growing in favor, but unfortunately, in many schools where chemistry is taught, the difficulties in the way of this method are still thought to be real. Even in these, chemistry to be truly useful should be presented as a study of phenomena, by experiments, instead of what somebody has said about phenomena in books.

I have therefore tried to construct a course of experiments suited to the use of the beginner, at his laboratory desk, and to the use of the teacher for his class of beginners, where facilities for students to work for themselves seem to be out of reach.

The study of any subject by experiment combines two kinds of exercise; mechanical and mental operations go hand in hand. On this account experimental investigation is a complex and difficult work. All that can be done to make it less so for beginners is to make one or the other, the mechanical or the mental processes, predominate in our elementary course of instruction. Then which shall it be? The mechanical of course stands first, in one sense, for there will be no phenomena to study until apparatus is selected and arranged to exhibit them. But, on the other hand, a wise selection of apparatus and conditions cannot be made by one who has not already acquired some skill in tracing the relations of cause and effect, and some experience in the application of experimental methods. I think we should first cultivate the power to observe exhaustively and to detect relations, — that we should make the mental more prominent than the mechanical in the elementary study of chemistry. Accordingly:

In this course of experiments the mechanical operations are described in quite minute details. Exactly what is to be done is told, but what is to happen, and the meaning of it, is for a time withheld. Exceptions to this plan will be found in the description of processes which are simply means to secure conditions, and in the statement of facts which may be needed for immediate use. But in general the phenomena which hold the chemistry of substances or processes are left for the student to discover. See, for example, page 35, or pages 85, 86.

I know that much stress is, by many, laid upon the industrial value of an instrument-making course in chemistry. But it seems to me that the study of chemistry is not primarily to teach mechanics, and that the use of tools and the possession of mechanical ingenuity can be better acquired in the industrial school or workshop, where these are the specific aims, than in the laboratory of the high school or academy, where the acquisition of knowledge for the sake of mental training is

the chief purpose. Home-made apparatus is not to be despised, but to be greatly respected, where nothing better can be had, for much can be done with the most common utensils, such as bottles, fruit-jars, tea-saucers, and oyster-cans. But certainly beginners can do better work with good facilities than with poor ones. And while there is so much in the market which is at once scientific and inexpensive, the student should be taught to reach more accurate results than are otherwise possible by the use of it. Productive ingenuity and skill must be founded on exact knowledge and clear thinking; they cannot precede these. Therefore:

The apparatus called for in this course has been selected from that which is made for, and approved by, chemists. The pieces are neat, simple, easily put together, always in market, and as cheap as possible for good scientific work. (See Appendix, Fig. 69.)

A brief summary of the most important facts and principles follows the experimental work, by which the student can check and correct his results. In this summary will be found the information which should be acquired by beginners in chemistry. I have tried to include in it only such things as will be of most value to the many who will finish the study of chemistry in the high school, and to the few also who are there to lay a foundation for college work. "Not how much we know is the best question, but how we have got what we know, and what we can do with it, and, above all, what it has made of us." — J. P. Leslie.

It is not well to undertake too much. It is not best to have the student's text-book burdened with matter which he is not expected to master. There is more education to be gained by extending the search for facts into other volumes than by skipping parts of the book in use. I have not given a long

list of experiments, but have tried to make a judicious selection, believing that a few typical ones well made and thoroughly studied, are far more useful than a larger number would be if studied in haste. What I mean by the thorough study of a few experiments in the treatment of a subject may be seen by referring to "Substitution," pp. 19–21: "Decomposition of nitric acid," pp. 92–95; or "Chlorides," pp. 141–145.

Additional work is better when provided by teachers for such pupils or classes as have time or talent to undertake it. I would make such work partake of the nature of research as much as possible. A student may be given some question to be answered by his own experiments, or two substances whose mutual reactions and results he is directed to investigate, or a single body whose properties he is asked to study and report. Some work of this kind I have given under the head of "Exercises." (See, for examples, pp. 39, 82, 100.)

Next in value to research in the laboratory stands research in the library. By all means teach the student how to make the results of his study, with apparatus and the text-book, the nucleus around which to group other facts, a center from which to extend his knowledge. From the following works the teacher can select abundant materials for this exercise, in kind and quantity suited to the varying wants of different individuals or of successive classes. Buckley's "Short History of Natural Science." Wurtz' "History of Chemical Theory." Wurtz' "Atomic Theory." Cooley's "New Text-Book of Chemistry." Cooke's "New Chemistry." Remsen's "Organic Chemistry." Remsen's "Theoretical Chemistry." Roscoe and Schorlemmer's "Treatise on Chemistry." Fresenius' "Qualitative Analysis." Douglas and Prescott's "Qualitative Analysis."

I have in all cases rejected dangerous experiments, but I have in many cases devised simple, safe, and efficient ways to study explosive and noxious substances. See, for examples, Hydrogen, pp. 29, 30, and Chlorine, pp. 138, 139.

The wood-cuts which represent the experiments are, with a single exception, Fig. 23, made from the photographs or drawings of the apparatus in actual use. For the selected cuts, which illustrate the descriptions of historical or industrial work, I am unable to give the credit which is due to their unknown authors.

POUGHKEEPSIE, June, 1886. L. C. C.

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OBSERVATION AND EXPERIMENT.

In the study of Chemistry we are to learn some things about the different kinds of matter. There are two ways in which these things have been found out, and in these same ways we can most easily learn what these things are. These two ways of studying nature are called *observation* and *experiment.*

Observation. — When I look at something which is going on, and watch carefully to see what happens, my act is an observation. To look at an object so closely that we can see its shape, its color, and whatever else is visible about it, is an act of observation.

If, for example, I desire to know as much as possible about a butterfly, the best way to learn it is to catch the butterfly, look at it intently, note down and remember what I see. The butterfly would show me that it has four wings, six legs, two long hair-like bodies (antennæ) reaching forward from its head with knobs upon their ends, two large, dark, and prominent eyes which do not close nor turn, and that the beautiful colors of its wings are due to a fine dust which is easily rubbed off by my fingers. All these facts I could learn by holding the insect in the hand and looking at it thoughtfully.

Knowledge which I get in this way is learned by observation.

Experiment. — But if, instead of only looking at an object as I find it, I do something to it to see how it will behave or appear in different conditions, this operation is an *experiment.*

Will 5 cubic centimeters of water dissolve as much as 10 grams of granulated sugar? I cannot find out by simply looking at sugar and water. In order to learn what the fact is, I may put the two things together in the right way, and if I do so I make an experiment. Thus:

Ex. 1. — I take a tall glass cylinder, *a*, Fig. 1, which is graduated to measure cubic centimeters, and pour in water

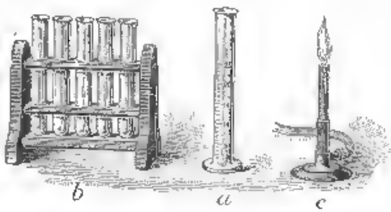

Fig. 1.

up to the 5 cc. mark.[1] I transfer this water to one of the thin round-bottomed cylinders, *b*, called a test-tube. I also weigh out 10 g. of granulated sugar[2] and put it into the water in the tube *b*.[3] I now warm the tube in the flame of a Bunsen lamp, *c*. There is danger of breaking the tube if I heat it too suddenly, or too long in one spot,

[1] If one must get along without a graduated cylinder, he may obtain 5 cc. very nearly by filling his test-tube one inch above the rounded bottom. The tube is supposed to be $\frac{5}{8}$ inch in diameter.

[2] If one must get along without a balance, he can obtain about 10 g. of dry sugar by filling a teaspoon twice.

[3] Fold a narrow strip of paper into the shape of a trough and lay this in the tube, which should be held in a slanting position. The dry sugar will slide safely down this trough instead of clinging to the wet walls of the tube.

and to avoid this danger I move it slowly in the flame to heat all sides evenly. When the liquid begins to boil I lift the tube into the hot air above the flame, where I can keep it hot without boiling it too vigorously. I watch to see

Whether the sugar remains, or becomes less and less.

Whether it all finally disappears.

If the liquid at length becomes, as it will, almost or quite transparent, we shall know that 5 cc. of *hot* water can dissolve 10 g. of sugar. I will then stand the tube in the tube-rack, and when it is cold I will look again and see

Whether 5 cc. of *cold* water can hold the 10 g. in solution.

Let us keep this syrup for use in another experiment.

The sap of some trees and the juices of some plants are *natural* solutions of sugar in water, but the quantity of sugar in 5 cc. of these juices is very small. Nothing but an experiment could have first shown that 5 cc. of water can dissolve so much sugar as we have found it to do.

Fig. 2.

But in experiments we often put things together in ways in which nature never does. For example, I wish to know how sugar will behave in strong sulphuric acid. Nature never puts these two things together, and the only way I can find out how they will act in the presence of each other is to bring them together. Thus:

Ex. 2. — I measure out 5 cc. of strong sulphuric acid with the cylinder *a*, Fig. 1, pour it into an empty test-tube, then rinse the cylinder and stand it on a small plate, Fig. 2. I now pour the sugar syrup made in the other experiment into this cylinder. I am ready now to bring the two together. I pour the acid in a slender stream into the syrup, and watch for every change that happens. I notice

A change in color.

A change in volume (size).

A change in temperature (warmer or colder).

A new substance unlike sugar or syrup or acid.

As soon as the experiment is over I write, in my notebook, a short account of what I did, and the results just as I saw them.

The fact is that a coal-black, bulky mass of hot carbon or charcoal is the result of bringing these two substances together.

The science of Chemistry is founded on facts which have been discovered by experiment, and the most natural way to study Chemistry is by the same means. The best way for the student is to make the experiments himself. The second best way is to see them made by a teacher. In either case the student should remember that the object of making experiments is to discover truth. An experiment may be pretty and interesting, but its value does not lie in its beauty. No experiment is good for anything in the study of Chemistry unless it helps to reveal some truth.

The student should remember, also, that it is not what he reads about experiments, or hears a teacher say about them, that is going to give him the best and quickest insight into Chemistry, but that which he sees with his own eyes and describes in his own words.

To study Chemistry by experiment the student should obey the following rules: —

1. Arrange the apparatus and use it *exactly* as directed.
2. Watch carefully to see *every* change which takes place.
3. Note accurately on paper every *important* change.
4. Compare these results with the facts stated in the book, and correct those which are found to be wrong.
5. Study carefully to see how certain inferences may be made from the results.

CHEMICAL CHANGES.

We already know by observation that there are changes all the time going on in bodies of matter. Some things change very rapidly, others very slowly. Wood changes to smoke and ash sometimes in a few minutes; a stone crumbles to powder only after many years. But nothing can forever stay exactly as it is.

The first thing we have to do in Chemistry is to become acquainted with these changes. How do they differ? How are they brought about, and what terms are used to describe them?

Ex. 3. — I take a piece of magnesium wire or ribbon about six inches long, grasp one end with a pair of pincers,[1] and hold the other end for a moment in the flame of the Bunsen lamp, Fig. 3. I see that

The metal becomes red hot, then bursts into flame.

Nothing finally remains but a crumbling white solid.

Ex. 4. — I now in the same way hold a piece of iron wire in the flame of the Bunsen lamp, and see that

The metal becomes red hot, but does not burn.

And finally, when cold, is the same substance as at first.

Both metals were changed by the heat, but in very different ways. The iron became hot in-

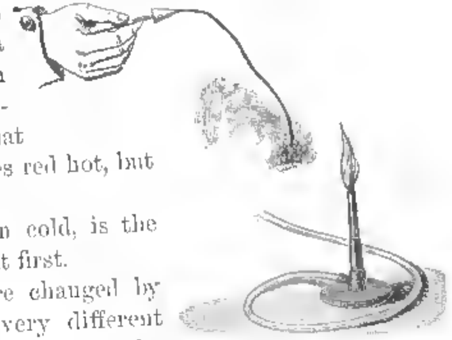

Fig. 3.

[1] A homely handle can be made by starting a split in one end of a stick. The wire can be inserted in the split and held as with pincers.

colorless gas which brightens the burning of a splinter. The shining droplets which coat the cold walls of the tube are *mercury*, and the gas in which a splinter burns with unusual brightness is *oxygen*.

This is a fine example of chemical change. But the most important thing to notice is, that in this change *one substance is broken into two* which are entirely unlike itself and unlike each other. Such a chemical change is called *decomposition*.

Decomposition of Potassium Chlorate. *Ex. 6.* — Potassium chlorate is a white solid. Before I heat it the coarse grains or crystals should be reduced to powder: I grind it in a mortar (Fig. 6). I put two grams of the powder into the ignition-tube,[1] Fig. 4. This quantity will fill about one inch of the tube. I put three or four cubic centimeters of blue litmus solution into one test-tube, *b*, and as much lime-water into a second tube, *c*, Fig. 5, and provide a good cork for each. I put the end of the rubber tube into the litmus, and then heat the chlorate just as I did the red oxide before. Watch for and describe

Fig. 6.

The changes in the chlorate.

The bubbles from the pipe in the litmus.

After a while I put a match-flame into the mouth of the tube and see that it burns with unusual brightness. This shows that the tube is filled with oxygen.

I then put the end of the rubber tube over into the lime-water in *c*, and close *b* with its cork, in order to keep its oxygen for use further on.

At length the boiling chlorate thickens, and soon after

[1] The tube must be clean and dry. A piece of dry cloth, or a sponge tied on the end of a wire or stick, is convenient for wiping tubes.

dries up completely to a white solid. The work is done. I stop the heat, remove the rubber tube, and cork the test-tube *c*, to keep its oxygen also for future use.

Has any change been made in the litmus or the lime-water?

THE FACTS. — By heating potassium chlorate it is first melted and afterward broken into two substances, unlike itself and each other. One is the white solid, left in the ignition-tube, and the other is *oxygen*. The chlorate is *decomposed*.

Oxygen, which has appeared in both these experiments, is an important substance, and as soon as we are through with the special study of chemical changes we will examine it fully. At present we will make two experiments with it.

Combination. — What will happen if a bit of coal is heated in oxygen?

Ex. 7. — I wind the end of a small wire around a little splinter of charcoal, heat the charcoal until it holds a spark of fire, and then lower it into the oxygen in the test-tube *c*, Fig. 5, over lime-water. Notice

What effect is produced on the spark.

Whether the charcoal wastes away.

Will the oxygen brighten a match-flame afterwards?

I now cover the mouth of the tube with my finger and shake it briskly.

What change takes place in the lime-water?

THE FACTS. — Charcoal with a dull red spark will glow brightly in oxygen and burn away rapidly; the oxygen is used up at the same time, and the lime-water afterward becomes turbid and white.

But we know that oxygen will not whiten lime-water: this was proved in Ex. 6. (How was it proved?) Charcoal also will not whiten lime-water. But the burning of the

3. *Find the boiling-point of alcohol, Fig. 30.*

4. *Find the boiling-point of a mixture of alcohol and water made in the proportion of one volume of alcohol to two volumes of water.*

Use the apparatus shown in Fig. 30.

Note the temperature when the boiling begins.

Turn the lamp low and let the boiling go on slowly until about 5 cc. of distillate is caught. Then change the test-tube.

Note the boiling-point again.

Repeat this several times, and then compare the distillates, by their odors and by means of a match-flame.

Which contains the most alcohol?

Does the liquid in the flask still contain alcohol?

The fact is that two liquids which have not the same boiling-point can be roughly separated by this process of distillation. It is called *fractional distillation.*

5. *Find by evaporation, whether the water in use holds any solid matter in solution.*

How, by the use of the balance and the graduated cylinder, can you find how much of this mineral substance the water contains?

CHEMISTRY OF THE ATMOSPHERE.

Not one hundred years ago the air was thought to be an element; that it is not was proved by the great French chemist Lavoisier.

Lavoisier's Experiment. — The apparatus which he used was much like that shown in Fig. 33. A small quantity of pure mercury was put into a flask which was placed over a furnace. The flask had a long, slender neck, which

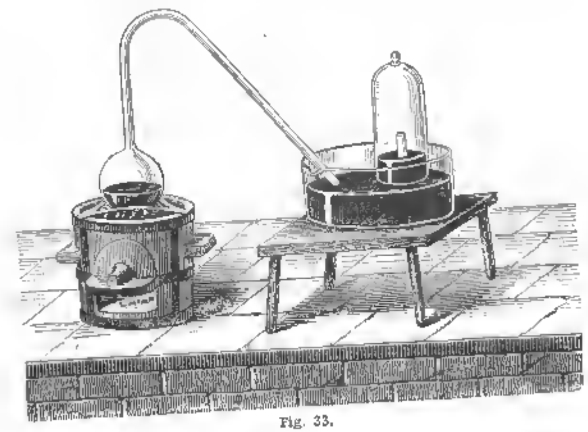

Fig. 33.

reached over into a pan of mercury. Standing mouth downward in this pan was a jar filled with air, and the neck of the flask was bent up into it.

When all was ready, Lavoisier lighted the fire in the furnace and kept it burning all the time for twelve days. On the second day he saw little red flakes of something swimming around on the surface of the mercury. For four or five days afterward the quantity of this red substance

increased while the quantity of air in the receiver diminished. For some time longer the heat was kept up, but no further change took place, and this part of the work was done. He had less air in the apparatus than at first, shown by the mercury rising in the jar, but instead of the air which was lost he had the new red substance in the flask.

What was this red substance? To find out, Lavoisier heated it in a tube so fixed that any gas which should be produced would be caught in a vessel over mercury. The red substance became black, then began to waste away while bubbles of a colorless gas were caught in the vessel prepared for the purpose, and globules of shining mercury gathered on the walls of the tube above the heated part. What was the colorless gas? Lavoisier plunged a candle-flame into it; the candle burned with a dazzling light. The gas was *oxygen*.

But whence came this oxygen to combine with the mercury when it was heated with air in Lavoisier's flask? The air must have given it to the mercury, and so the experiment proved that oxygen is one constituent of air.

In the flask and the glass jar (Fig. 33) there was still left a large quantity of air-like substance. But on plunging a candle-flame into it the flame was put out as it would have been in water. Plainly it was not air. In fact it was the gas called *nitrogen*.

Lavoisier's experiment proved that oxygen and nitrogen are two constituents of air. There are indeed a few other gases in the atmosphere beside these, but in comparison with these the quantity of them is small. Oxygen and nitrogen are the two chief constituents of the air.

NITROGEN.

When a substance burns in air it takes the oxygen and leaves the nitrogen. Lavoisier burned mercury, but sulphur and some other things will burn more quickly, and may be used instead. Let us try sulphur, and afterward phosphorus.

Ex. 43.—I cut a slice half an inch thick from a cork which is much smaller than the mouth of my bottle. I shape the top of the cork into a shallow cup and rub it well with crayon-powder, or better with a paste of moistened plaster of Paris. I put sulphur in this cup, place the cup on the shallow water in the water-pan, set fire to the sulphur, and put a bottle bottom upward over it, as shown in Fig. 34. Describe

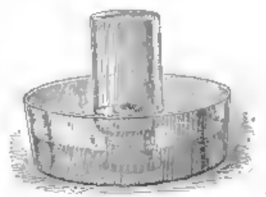

Fig. 34.

The flame of the sulphur.

The action of the water when the burning is over.

The change in the gas after long time standing.

Ex. 44.—I use a piece of phosphorus, not larger than a good-sized kernel of wheat, with another bottle holding about 200 cc. I treat it just as I did the sulphur, and again describe the flame, the action of the water afterward, and the appearance of the gas inside after standing some time over water.

But the handling of phosphorus is dangerous, unless it is done with great care. Phosphorus takes fire easily and burns the flesh cruelly. Cut it under water, lift the piece with the knife-blade, dry it by gentle contact with filter-paper, and put it into a *dry* cup. Never handle phosphorus without using the greatest care.

Ex. 45.—When the gas in the bottle used in Ex. 43 has become clear I slip a square of glass or of cardboard under the mouth of the bottle, lift it out of the water, turn it mouth upward, stand it on the table and leave it covered.

I at once ignite a match, uncover the bottle, and insert the flame; the nitrogen will quench it. I leave the bottle uncovered. I treat the bottle used in Ex. 44 in the same way; the nitrogen again puts out the flame. I leave this bottle, also, uncovered.

Ex. 46. — I now again insert a match-flame in the bottle first left uncovered, and afterward in the other. The flame is not quenched.

What does this prove?

Ex. 47. — I now add a little blue litmus-water to the water in the bottle in which sulphur was burned.

Note the change of color. Compare Ex. 8.

What causes this change of color?

Ex. 48. — I add blue litmus-water to the water in the second bottle which was left uncovered in Ex. 45: it changes from blue to red.

Can you explain this change of color?

Burning of Sulphur. — Sulphur, when burning with its feeble blue flame, combines with oxygen, and the two become sulphur dioxide. The water soon dissolves the whitish vapor and rises into the vessel, and at last fills just the space which the oxygen of the air occupied at first, while the nitrogen of the same air remains above the water (Ex. 43).

The sulphur dioxide shows its presence in the water by reddening the blue litmus, Ex. 47, as it did in Ex. 8.

Burning of Phosphorus. — When phosphorus is used the action is much the same. It combines with the oxygen of the air and forms phosphoric oxide, which fills the vessel as a milk-white vapor. Water soon dissolves this oxide, and the nitrogen of the air is left as before.

The phosphoric oxide also shows its presence in the water by reddening blue litmus (Ex. 48).

Properties of Nitrogen. — Nitrogen is a colorless gas (Exs. 43, 44). It is lighter than air (Ex. 46), but a liter of it weighs fourteen times as much as a liter of hydrogen. It will quench fire (Ex. 45), because it cannot unite with the elements of the fuel as oxygen does. In fact, nitrogen is the least active of the elements. It will not only quench fire, but if breathed instead of air it will quench life also. Yet it cannot be poisonous, since we inhale it with every breath without injury. It is the oxygen of the air that sustains life, and it is the absence of oxygen, and not the presence of nitrogen, which causes death when pure nitrogen is breathed.

Other Constituents of Air. — The air also contains water in form of invisible vapor. This is proved by placing a piece of caustic potash in an open dish. The potash will very soon become wet, and if left for some time it will be dissolved by the water which it takes from the air. Try it. The moisture to be seen on the outside of a vessel of ice-water in summer is the condensed water-vapor of the air. Dew and hoar-frost are also the water of the air, changed by cold from vapor to liquid and solid forms.

The air also contains carbon dioxide. This is shown by lime-water, which if left exposed in an open vessel will become covered in a few hours with a white crust. Try it. This crust is the same substance which is seen in lime-water after it has received carbon dioxide (Ex. 7).

The air also contains ammonia in very small quantities.

Nitrogen, oxygen, water-vapor, carbon dioxide, and ammonia are the regular constituents of the atmosphere. Our next question is, How much of each of these substances is to be found in air?

The Analysis of Air. — We set out now to find how many cubic centimeters of nitrogen and how many of oxygen and carbon dioxide there are in 100 cc. of air.

To do this we will imprison a vesselful of air, and then run into it a liquid which will absorb both the oxygen and the carbon dioxide completely, and leave the nitrogen. We can then measure the nitrogen which is left, and we can find out how much there was of the other two, by measuring the liquid which has gone into the tube to take their place.

Ex. 49. — OUR APPARATUS. — I take a test-tube, *t* (Fig. 35) to hold the air. A six-inch tube, $\frac{5}{8}$ inch in diameter, will do; an eight-inch tube of the same diameter is better. The rubber stopper, *c*, is so large that its small end will enter the tube only about a half-inch. It has two holes; to close one I have a solid rod of glass, *s*; for the other, a glass tube reaching just a very little below the cork, as shown. A piece of thin rubber tubing, *h*, is cut about six inches long. There is a pinch-cock, *p*, by which its walls may be pinched so as to close it completely. *F* is a small glass funnel.

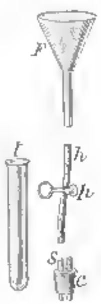

Fig. 35.

The lower end of *h* I stretch over the tube in the cork *c*, and its upper end I fix over the stem of *F*, and then I place the funnel in the clamp of the support, as shown in Fig. 36, and remove the rod *s*.

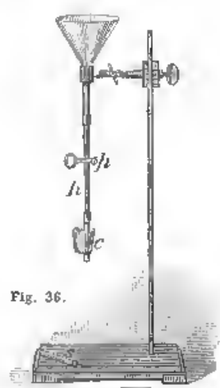

Fig. 36.

THE LIQUID. — To absorb the oxygen and carbon dioxide gases I use a mixture of pyrogallic acid and potassium hydrate.

I take a small teaspoonful of the solid acid and pour on it 10 cc. of water; it will soon dissolve. To this I then add 5 cc. of strong solution of potassium hydrate, and *at once* pour it into the funnel. Next, I hold the dish

below the cork and open the pinch-cock *p* a moment, to let the liquid run down and fill the tubes completely. I carefully take off the drop, which hangs at the lower end of the tube below the cork, with a piece of filter-paper.

I press the tube *t* up over the cork until the joint is air-tight, as seen in Fig. 37, and after a minute I put the rod *s* into the open hole of the cork. I have now imprisoned a tubeful of air; none can get out, and no more can get in.

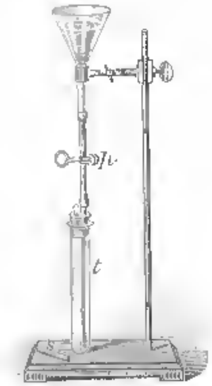

Fig. 37.

I left the hole in the cork open, because if it were not open the pressure of the cork would crowd the air below, and there would be too much in the tube; and then, too, handling the tube warmed it, and the volume of air changes with heat. With the hole open, the air in the tube soon comes to be just as warm and just as much pressed as the air outside. Whenever a gas of any kind is to be measured its *temperature* and *pressure* must be the *same as those of the air outside.*

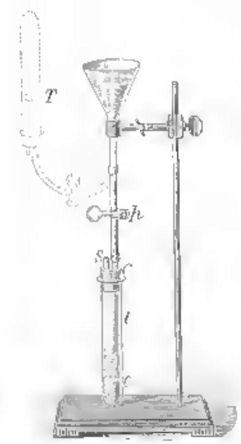

Fig. 38.

THE ABSORPTION. — I now press the pinch-cock *p*; a little stream of the liquid falls into *t* at once, and then drops follow, or, if the tube be slightly inclined, a slender stream will flow down its side. It will continue to enter as long as there is any oxygen or carbon dioxide for it to absorb, and then stop. The gas which is left in the tube is nitrogen.